National Aeronautics and Space Administration

GaN-Based Power Bus Converter with Autonomous Adaptive Control for Deep Space Small Spacecraft Power Subsystems

Principal Investigator: Dr. Ansel Barchowsky (346)

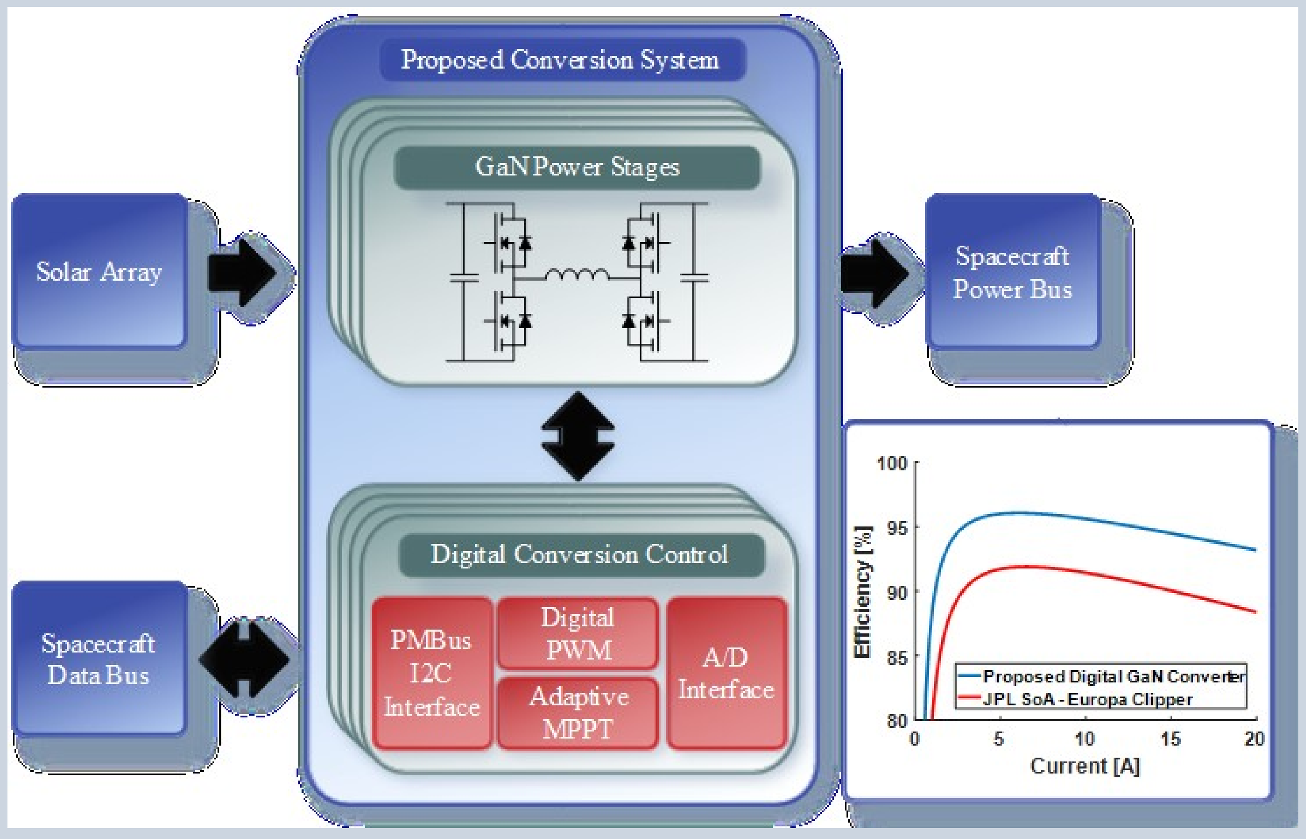
Dr. Miryeong Song (514), Greg Carr (346), Chris Stell (346), Dr. Raghav Khanna (University of Toledo)

Program: Topic Area Research and Technology Development

Project Objectives

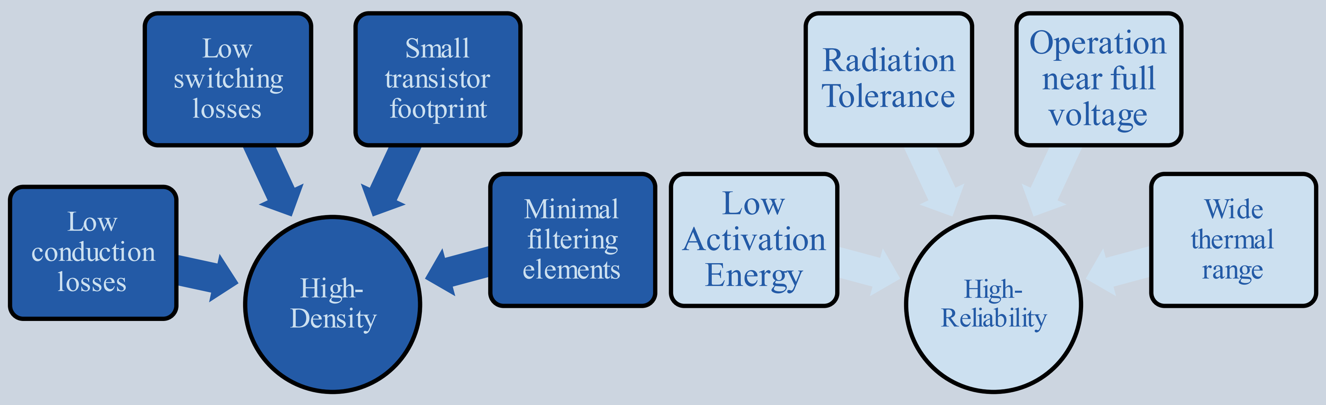
Compact, Efficient, Power Systems

- Provide high efficiency (>96%), high density (>2W/cm3) power converters and systems for future JPL spacecraft
- Develop fault-tolerant digital controls to replace analog ICs
- Develop ripple correlation model reference adaptive MPPT controller for optimized photovoltaic performance
- Provide pathway to system integration for Flagships, SmallSats, and more



GaN-Based Power Conversion

- GaN performance benefits over Si:
  - Reduced C_{ISS} by a factor of 10 to 20
  - Reduced C_{OSS} by a factor of 3 to 10
- Device qualification is ongoing and commercial vendors are engaged to develop next-generation control ICs.



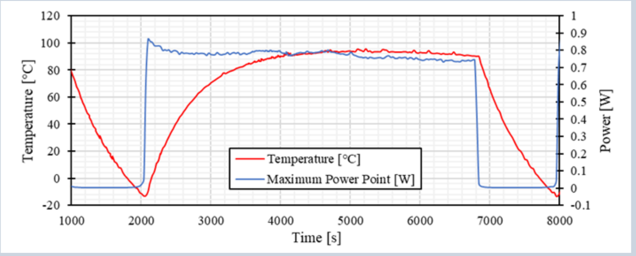
FY' 19 Results – System and Controller Development

MPPT in Deep-Space Systems

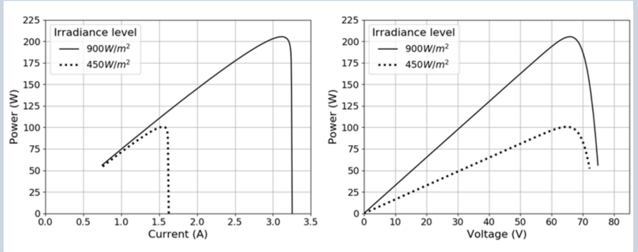
- Environments cause rapid changes in insolation and temperature
- MPPT allows for autonomous control over system operating point
- Fluctuations in orbits and degradation of system elements demand changes in control points over the mission

Adaptive MPPT Algorithm Design

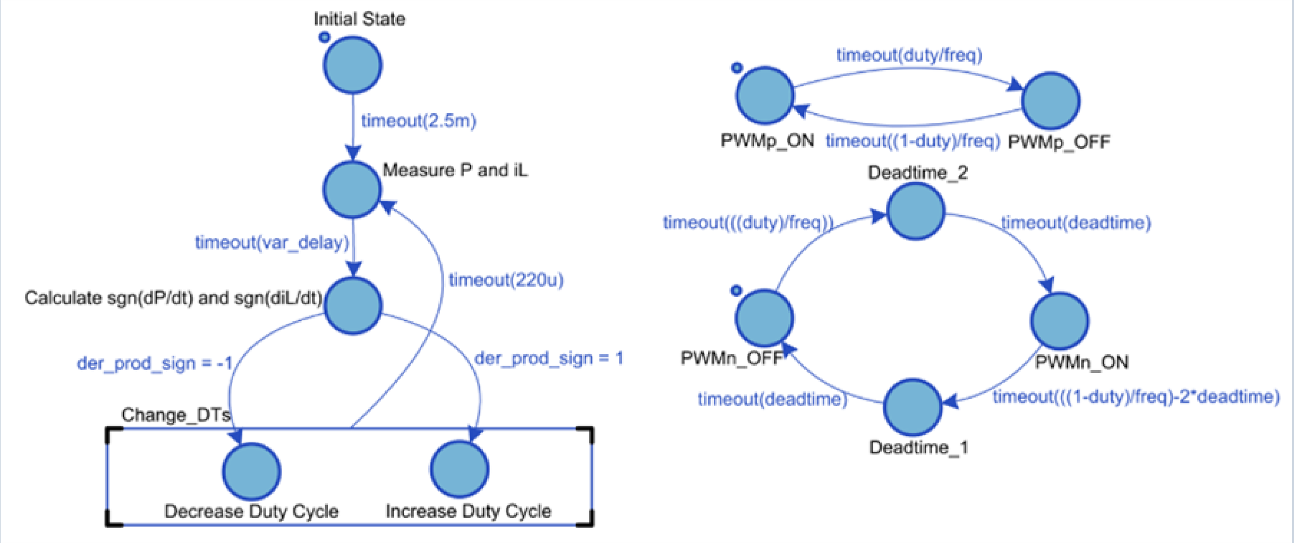
- The MPPT algorithm from U. Toledo has two key elements:
  1. Ripple Correlation Control for rapid convergence to the MPP without steady state PV perturbation
  2. Model reference adaptive control to smooth transients and avoid collapsing weak PV arrays



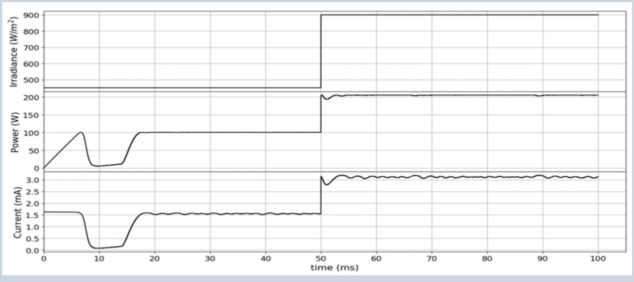
SMAP Solar Array Variation



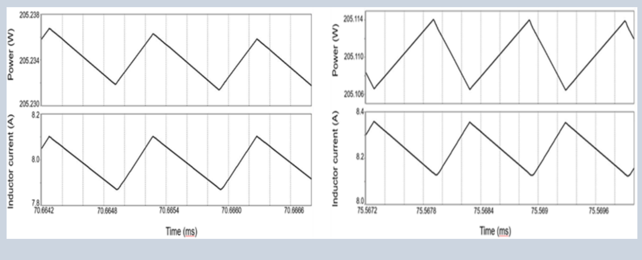
Modeled V_{MPP} and P_{MPP} for SMAP Data



State Machine for Ripple Correlation Controlled Duty Cycle Derivation



Simulated MPP Transient Step Response

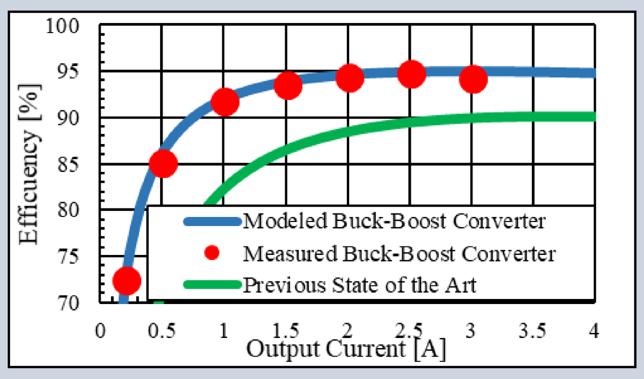


Simulated Ripple Response During Step

FY' 19 Results – Hardware Development

Four-Switch Non-Inverting GaN-Based Buck-Boost Converter

- The JPL Buck-Boost testbed provides solar array regulation and power system control on a single PCB
- Control functions are implemented on a radiation-tolerant ARM Cortex M0+
- Telemetry functions are implemented in the conversion controller, eliminating the need for a power bus controller



Simulated MPP Transient Step Response

Parameter	Design Value
Input Voltage	10 – 100 V
Output Voltage	22 – 36 V
Processing Power	500 W
Switching Frequency	200 - 1000 kHz
GaN Device	GS66516B

Simulated MPP Transient Step Response

Power Subsystem Features

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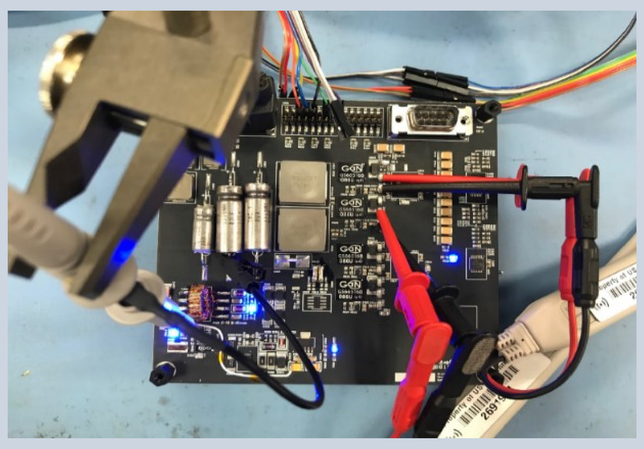
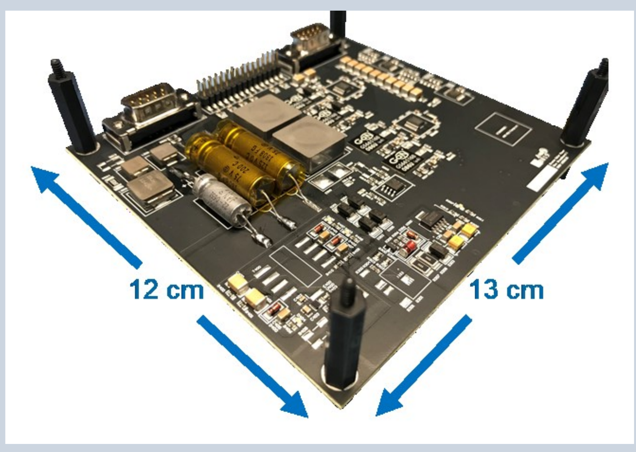


Simulated MPP Transient Step Response

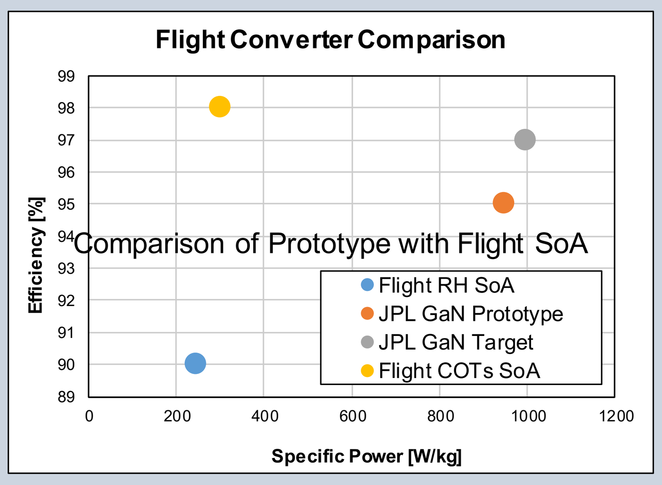


Simulated MPP Transient Step Response

Benefits to NASA and JPL

Efficiency for Flagships

For next-generation flagship missions, high-powered instruments and compact form-factors will demand high-efficiency power systems. This work increases solar array efficiency by 5%, power density by a factor of 4.8, and specific power by a factor of 6. For a primary-battery mission like Europa lander, these metrics provide additional days of scientific data collection. For rovers like Mars Sample Return, they equate to more mass, power, and volume for science payloads.

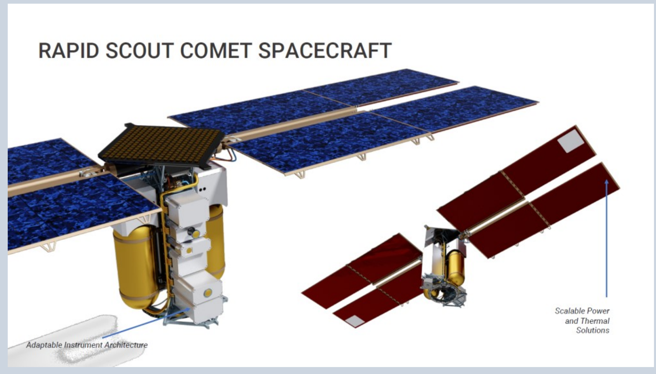


Comparison of Prototype with Flight SoA

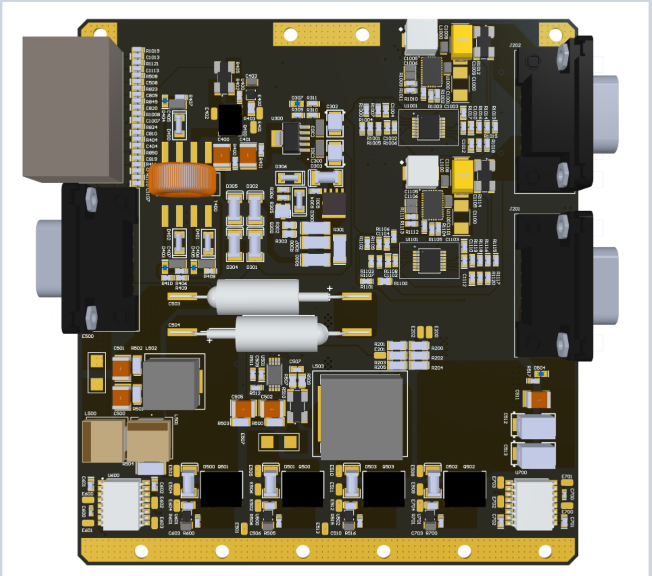
Rendering of the Europa Lander Mission Concept

Reliability for Small Sats

For Small Sat platforms, the developed system provides the form-factor and efficiency of a commercial platform, coupled with the reliability and design margin of a JPL power subsystem. By combining the buck-boost system with an integrated isolated converter, point of load converters, and load switches, 50 – 200 kg spacecraft like RapidScout or SIMPLEx can be supported on a single 250 W EPS PCB.



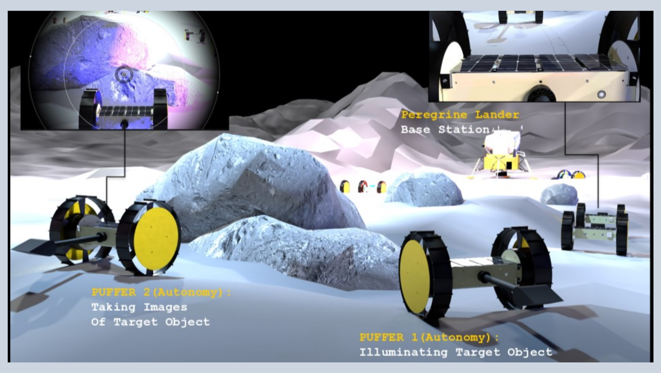
Rendering of the RapidScout Mission Concept



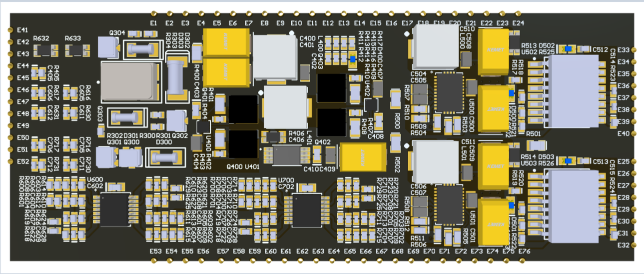
Design of RapidScout 250 W Prototype EPS

Density for Even Smaller Sats

Several JPL mission concepts, like the PUFFER rover, require flight-qualified power subsystems in form-factors that don't exist. For these missions, the developed conversion system has been scaled to a 25 W, 4cm x 10cm PCB that provides full EPS functionality and enables compact rover solutions.



Rendering of the Lunar PUFFER Mission Concept



Design of 25 W Lunar Puffer Prototype EPS

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

PI: Dr. Ansel Barchowsky
E: ansel.barchowsky@jpl.nasa.gov
P: 818-354-0576
M: 626-658-5752

www.nasa.gov

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